THE FEDERAL COMMUNICATIONS COMMISSION SPECTRUM AUCTIONS AND JOINT VISION 2010: WILL THE FCC SPECTRUM AUCTIONS HINDER THE DEPARTMENT OF DEFENSE'S ABILITY TO EXECUTE JOINT VISION 2010?

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This thesis examined the impact of the Federal Communications Commission (FCC) frequency auctions on Joint Vision 2010. Since 1993, the FCC has conducted spectrum auctions which auctioned portions of the EM spectrum to industry. Included in the auctions have been portions of the EM spectrum allocated to the DoD. Defense systems are extremely dependent upon access to the EM spectrum. DoD communications, sensors, and command and control systems all use the EM spectrum. The study analyzed the impact of the auctions on DoD systems by looking at frequency bands that are being used by DoD systems and at frequency bands that future systems will use. The study examined some solutions to this problem including using new and evolving technology, government options and industry solutions. The study concluded that DoD can execute Joint Vision 2010. However, DoD must take immediate steps to assure to the EM spectrum. These steps include investing in technology that will make DoD more spectrum efficient and working closely with industry to foster better relations between DoD and industry.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

THE FEDERAL COMMUNICATIONS COMMISSION SPECTRUM AUCTIONS AND JOINT VISION 2010: WILL THE SPECTRUM AUCTIONS HINDER THE DEPARTMENT OF DEFENSE'S ABILITY TO EXECUTE JV 2010? By MAJ Keith June. 76 pages.

This thesis examined the impact of the Federal Communications Commission (FCC) frequency auctions on Joint Vision 2010. Since 1993, the FCC has conducted spectrum auctions which auctioned portion of the EM spectrum to industry. Included in the auctions have been portions of the EM spectrum allocated to the DOD. Defense systems are extremely dependent upon access to the EM spectrum. DOD communications, sensors, and command and control systems all use the EM spectrum.

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The study concluded that DOD can execute Joint Vision 2010. However, DOD must take immediate steps to assure access to the EM spectrum. These steps include investing in technology that will make DOD more spectrum efficient and working closely with industry to foster better relations between DOD and industry.

To my Mom and Dad, Lucile and Henry June.

Thank you for being such great and wonderful people

May I never forget what you have given me.

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LIST OF ABBREVIATIONS

ASDC3I	Assistant Secretary of Defense for Command, Control and Communications
AWE	Advanced Warfighting Experiments
C2	Command and Control
CCIR	International Telegraph and Consultative committee
CDMA	Code Division Multiple Access
CNR	Combat Net Radio
DC	Direct Current
DOD	Department of Defense
DOIM	Directorate of Information Management
DISN	Defense Information Systems Network
DSP	Digital Signal Processing
EEC	European Economic Community
EHF	Extremely High Frequency
EM	Electromagnetic
EMSE	Enhanced Mobile Subscriber Equipment
EPLRS	Enhanced Position and Location Reporting System
FM	Frequency Modulation
FDMA	Frequency Division Multiple Access
FCC	Federal Communications Commission
GAO	General Accounting Office
GHz	Gigahertz

GPS	Global Positioning Satellite
HF	High Frequency
Hz	Hertz
IP	Internet Protocol
JCS	Joint Chiefs of Staff
JSC	Joint Spectrum Center
JSTARS	Joint Strategic and Reconnaissance System
JTRS	Joint Tactical Radio System
JV2010	Joint Vision 2010
IRAC	Interagency Radio Advisory Committee
KHz	Kilohertz
LAN	Local Area Network
LF	Low Frequency
MCS	Maneuver Control System
MHz	Megahertz
MSE	Mobile Subscriber Equipment
NTIA	National Telecommunications and Information Agency
NTDR	Near Term Digital Radio
OBRA	Omnibus Budget Reconciliation Act
SHF	Superhigh Frequency
SINCGARS	Single Channel Ground and Airborne Radio System
TI	Tactical Internet
TOC	Tactical Operations Center

TDMA	Time Division Multiple Access
TF XXI	Task Force XXI
UHF	Ultrahigh Frequency
VLF	Very Low Frequency
VHF	Very High Frequency
WIN	Warrior Information Network

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CHAPTER 1

INTRODUCTION

> Throughout history, gathering, exploiting, and protecting information have been critical in command, control, and intelligence. The unqualified importance of information will not change in 2010. What will differ is the increased access to information and improvements in the speed and accuracy of prioritizing and transferring data brought about by advances in technology. While the friction and the fog of war can never be eliminated, new technology promises to mitigate their impact. Sustaining the responsive, high quality data processing and information needed for joint military operations will require more than just an edge over an adversary. We must have information superiority: the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same. (US DOD 1997, 3)

The Joint Chiefs of Staff have provided military planners with an operationally based template for the evolution of the Armed Forces over the next decade (US DOD 1997, 3). Based on this developing framework, future operational concepts will require improved command, control and intelligence. The ability to collect, process, and disseminate an uninterrupted flow of information, while exploiting or denying the enemy's ability to do the same, is critical to the success of these new strategies. Assured access to the electromagnetic spectrum (EM) will be as critical to the military in the future as it is today. This thesis will be an examination of the impact of the Federal Communications Commission's (FCC) spectrum auctions and the related spectrum reallocation on Department of Defense (DOD) operations. Specifically it will attempt to determine whether spectrum auctions will hinder DOD's ability to implement Joint Vision 2010. Additional questions the study will answer include:

1. How will DOD compete with private firms to maintain access to desired portions of the spectrum who are willing to pay billions of dollars for its use?
2. Do the auctions present a major threat to the DOD use of the spectrum?

3. What will auctions cost the DOD?

4. What steps can the DOD take to maintain access to the EM spectrum?

5. How might future technologies change the auction's debate?

Use of the EM spectrum is critical to the DOD. Thousands of DOD systems use the EM spectrum. These systems include communications, sensors, radar, navigational aids and command and control systems. Perhaps Omar Bradley said it best when he said, "Congress can make a man a General, but only communications can make him a commander" (Campen 1992, 134). The Gulf War is often called the first information war. The first Iraqi systems targeted for destruction were command and control systems, which were very dependent upon the use of the EM spectrum. Denying an adversary the use of the EM spectrum greatly reduces his ability to exercise command and control and his ability to see the battlefield through the use of sensors and radar. From Global Positioning Satellites (GPS) to the Single Channel Ground and Airborne Radio System (SINCGARS) to Joint Stars (JSTARS), the success of any modern military operation is contingent upon access to and control of the EM spectrum. US advanced technology has been the key to past successes on the battlefield. As will be outlined in this study, newer systems, such as mine detection, stealth technology, and high capacity communications networks, are heavily dependent upon the EM spectrum. One must recognize that these systems represent only a small part of the DOD spectrum use. Figure 1 illustrates the range of EM spectrum and how DOD systems use the EM spectrum.

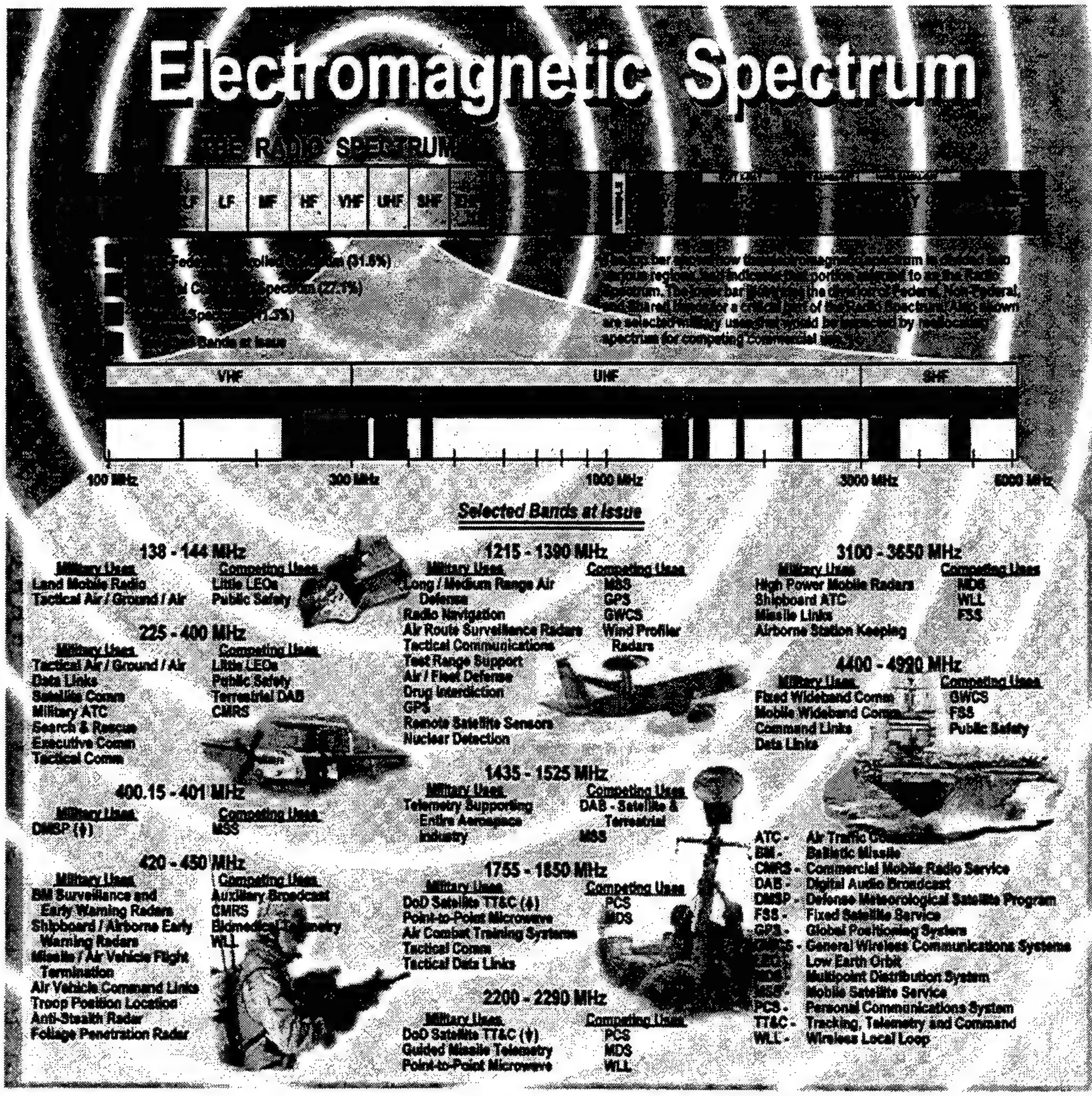

Figure 1. Joint Spectrum Center. 1998. Reproduced by permission of the Joint Spectrum center.

The EM spectrum covers the scope from 10 kilohertz (kHz) to 100 Gigahertz (GHz). Communications planners sometimes refer to the range as being from Direct Current (DC) to daylight, DC being the low end of the EM spectrum and visible light being at the high end. The laws of physics make certain parts of the EM spectrum better at transmitting certain types of information. The EM spectrum is broken into numerous

bands: these bands include low frequency (LF), very high frequency (VHF) up to extremely high frequency (EHF).

A frequency is a description of the number of cycles per second of a radio wave. The unit of measure used to describe a frequency is a hertz. As one moves higher in the frequency band, the potential for transmitting a larger amount of information also increases. However, as one moves higher in the frequency band, the amount of power required to transmit also greatly increases as the size of the antenna decrease. Atmospheric conditions, time of day, frequency band, and other factors all influence how far a particular frequency may propagate. A very general rule is the higher the frequency the greater the amount of information that can be sent over the frequency. Very little information can be transmitted over high frequencies (HF). Additionally, lower frequencies are more subject to interference by natural phenomenon, such as lightening. Much higher rates of information can be sent over superhigh frequency (SHF) systems. In theory, one could transmit huge amounts of information over EHF systems; however, the power requirements to move this information over any usable distance make this impractical for mobile systems.

Bandwidth is perhaps the most confusing term in use today. Technically, bandwidth refers to a range of frequencies. For instance, the bandwidth available for one channel in the older vehicular radio system (VRC)-12 series radio is 5 kHz. However, bandwidth is used by many to describe data capacity. For instance, the amount of information that could be carried over a satellite channel is often expressed as bandwidth. This is not to say that this usage is incorrect.

Another basic component of understanding the EM spectrum is modulation. Different modulation and coding schemes are used in communications systems. In all cases, voice, data, imagery, and video are converted from their original format for transmission through free space using radio waves. Advanced modulation techniques improve overall throughput thereby improving the efficiency of a given medium. Amplitude modulation (AM) and frequency modulation (FM) systems represent a voice signal either by varying the frequency or amplitude of a given frequency. FM and AM are the two best-known modulation systems. FM radios were invented by Motorola and were used extensively by the US Army in the Second World War. Multichannel systems operating in the higher VHF bands were used extensively in the 1950's. Other modulation and multiple access systems include frequency shift, code division multiple access (CDMA), and time division multiple access (TDMA). These innovations have greatly improved the efficiency of a given frequency or frequency band. Many of these modern modulation systems are complex algorithms used to compress signals and even provide error-correcting capabilities.

To fully understand and appreciate many of the issues involved with this problem one must also have some understanding of analog and digital communications. An analog signal is a continuous signal, such as a person speaking. The spoken voice contains many sounds that have varying loudness and can have an infinite number of values between the loudest and softest sounds. Analog systems replicate the human voice. A digital signal consists of zeros and ones. The transmitted information consists of zeros and ones making it easier to correct problems during transmission. Also, digital

transmissions make it possible to create other modulation methods, some of which will be explored later.

Technological advances have pushed frequency use well above 6 GHz. New technologies, such as millimeter wave radio, are pushing usable frequencies to around 30 GHz; however, the vast majority of systems in the foreseeable future will operate below 3 GHz. Military systems must be able to deploy easily and quickly. Systems in the high end of the spectrum require large power systems making them impractical for military use, although millimeter radio will have some military applications.

The last decade has seen an explosion of new technologies in the communications industry. Wireless systems have been among the chief technologies in revolutionizing these global changes. Wireless systems, including cellular telephones, pagers, and wireless Local Area Networks (LANs), are just a few of the new and emerging technologies. The Iridium satellite constellation is already in place, allowing phone calls to be made from literally anywhere on earth. Iridium is but one of hundreds of new commercial systems.

The Information Age Gold Rush

Nations around the world have embraced wireless systems. Wireless systems are cheaper, more efficient and much quicker to employ than existing hard wire systems. Governments around the world have struggled with new ways to both manage and regulate these new technologies. The existing governmental regulatory structure has proven incapable of regulating these new technologies.

The most basic ingredient of these new technologies is the use of and access to the EM spectrum. By the late eighties, few frequencies were available in existing

frequency bands. Given the tremendous demand for additional frequencies, the US Government and other industrialized nations sought new ways to manage a very limited resource. Prior to the nineties, only portions of the EM spectrum, including broadcast frequencies were closely controlled. The growth of the car phone industry in the early eighties demanded some new system of allocating radio frequencies. The FCC, the Federal Government's communications regulatory agency, used several systems to allocate frequencies. These included first-come, first-serve systems and lotteries. All were heavily criticized, and in fact, companies sued the FCC as the result of these allocation methods. The eighties also saw an explosion in the US federal debt. By the end of the eighties, the US federal debt exceeded $3 billion. By the end of the eighties, several members of the FCC proposed a new method of allocating spectrum to private industry. Dr. Roger Stanley and John Williams, two senior FCC engineers, argued that frequencies should be viewed as a limited and valuable commodity. As such, their idea was to allow the free market to determine the value of the EM spectrum. They argued that spectrum users, such as members of industry, should be allowed to bid for portions of the EM spectrum. At their inception, spectrum auctions were looked upon as a radical method of frequency allocation and were initially opposed by many in industry. The use of the EM spectrum had always been free of charge. In fact, many compared it to air, a free and inexhaustible resource. Broadcasters were perhaps the most vocal members of industry opposed to the auction idea. Although broadcast frequencies were not a part of the initial auction idea, broadcasters feared that eventually all portions of the EM spectrum might be auctioned.

The departing Bush administration and the newly arriving Clinton administration began to explore the idea of spectrum auctions. The administration quickly embraced the auction idea. They saw spectrum auctions as a way of generating billions of dollars in much needed revenue to help balance the federal budget. Additionally, the Clinton administration saw auctions as a win-win proposition. The American people won by the additional revenues generated by auctions, and by the thousands of new jobs that would be created in the private sector. The communications industry won by a more efficient method of frequency allocation. The auctions idea also fit nicely into the Clinton administration's reinventing government initiative. The US Government conducted the first in a series of spectrum auctions beginning in 1993. The first auctions were viewed as a tremendous success generating billions in revenue. Global telecommunications firms including US West, Sprint, and other firms bid billions of dollars to buy portions of the EM spectrum across the United States. Vice President Al Gore referred to this first auction as the information-age gold rush. This modern-day gold rush ushered in a new era in the telecommunications industry. Sixteen auctions have been conducted since 1993, with four more planned by 2002. The auctions have raised over $20 billion so far and many more spectrum auctions are planned in the future. Other nations were very interested in the US auctions as evidenced by the presence of delegations from Poland, Germany, and Russia at the first auction.

The Idea of Spectrum Auctions

Spectrum auctions are not just an American idea. To be sure, the first spectrum auctions were, in fact, conducted in New Zealand in the late eighties. Spectrum auctions are being considered by many nations for a variety of reasons. Governments around the

world face huge fiscal deficits and are constantly exploring new ways to generate much needed revenue. Global telecommunications systems like Iridium and the Global Positioning Satellite (GPS) system require the same frequencies around the world. Satellite systems require the same frequency bands for worldwide use. In fact, some telecommunications companies are seeking to buy the same frequencies around the world or at least to have certain frequencies set aside for their systems. Radio frequencies do not respect international boundaries.

The problem is especially profound in Europe, given its population density and tremendous demand for communications systems. The telecommunications industry in Europe has seen phenomenal growth since the fall of the Berlin wall. Hungary, a country of some eight million, has over 600,000 cellular telephones (Hungarian telecommunications official, 1996). Essentially, every other working adult has a cellular telephone. The problem is equally pronounced in Western Europe. In 1998, the former state-owned telecommunications firms were privatized. New wireless companies were created overnight. As a result of the end of the Cold War, European nations drew down their military forces. Resources that had previously been dedicated to the military such as exclusive use of portions of the EM spectrum, became a thing of the past. Given the enormous success of spectrum auctions in the US and the tremendous requirement for additional frequencies in their own countries, European nations began to study auctions as a method to better manage the EM spectrum and generate additional government revenue. In the case of Europe, spectrum management is governed by the International Telegraph and Consultative Committee (CCIR), a European parliament body similar to

the American FCC, but consisting of delegates from the nations of the European Economic Community (EEC).

Auctions 1998--Department of Defense

Perhaps overlooked by all sides was the impact of the auctions on the DOD Defense. Within the federal government, the DOD is the biggest user of the EM spectrum. Full access to the EM spectrum is critical to the armed services' ability to command and control forces, to see the battlefield through the use of sensors, and to navigate ships, aircraft, and tanks. The demand for access is even more critical today given the services' heavy reliance on technology and information. In the rush to generate revenue, no in-depth study was conducted during this early period to determine the overall impact of the auctions on the DOD. The fall of the Berlin wall was the symbolic end of the Cold War. For nearly fifty years soldiers had planned on fighting World War III. The Cold War consumed huge amounts of national resources. With the end of the Cold War, the American people sought a peace dividend. If the US no longer faced another superpower, why not return some resources back to the American people? Other factors also played a role in limiting a DOD response.

Use of the EM spectrum is vital to US military forces. A typical Army division has almost 11,000 emitters operating from Very Low Frequencies (VLF<30 MHz) to above 3 GHz. Bear in mind that this Army division will probably operate with other services as a part of a Joint Task Force. A Joint Task Force (JTF) with elements for the other services would have even greater frequency demands. Given the services increasing dependence upon information technology, the demand for bandwidth will no doubt increase. Figure 2 shows the relationship between the National

Telecommunications and Information Agency (NTIA) and the FCC. The FCC is an independent federal agency chartered by the US Congress. It is not a part of the executive branch of government. By Federal law, the FCC manages and regulates civil use of the EM spectrum. The NTIA manages government use of the EM spectrum and serves as the Executive branch telecommunications advisor to the President. Executive branch users include the DOD agencies, the Departments of Justice, Treasury, Veterans Administration (VA) and others. The NTIA is a part of the Department of Commerce.

NATIONAL SPECTRUM MANAGEMENT

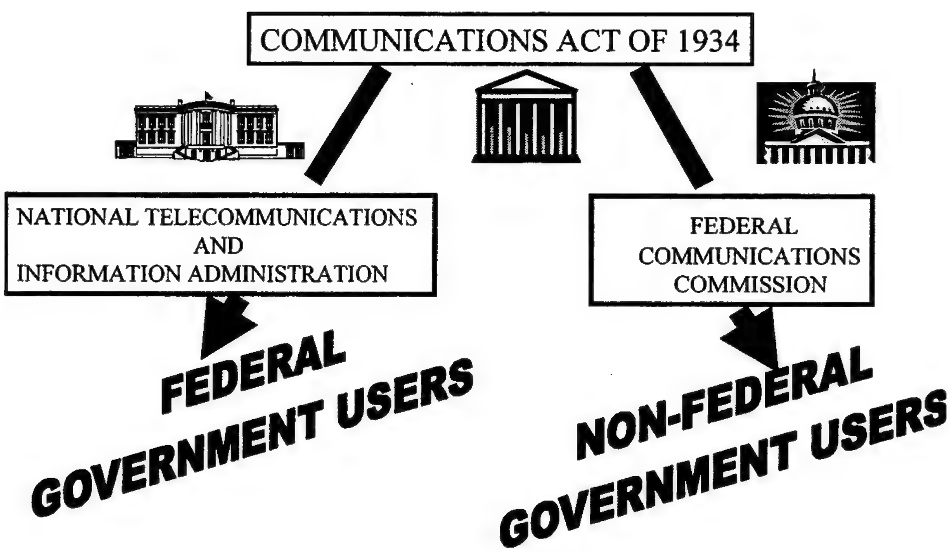

Figure 2. (Source: NTIA Homepage, 10 January 1999)

Federal agencies, including the three services, Departments of Justice and Treasury, VA and other federal agencies, have seats on the Interagency Radio Advisory Council (IRAC) which governs spectrum use for federal users. In theory, the NTIA and

the FCC have equal footing. In fact, the FCC has evolved into a much more powerful agency.

The president as Commander-in-Chief establishes defense policy. The Clinton administration's support for auctions severely limited the DOD response to the auctions. Additionally, the NTIA director is a presidential appointee. Congress and the president both appoint the FCC commissioner and panel. Both factors limited the DOD response to the auctions (NTIA, 1998).

There were other issues that limited DOD's response. The services had widely differing views of EM spectrum use. Each service has a seat on the IRAC, but there is no DOD seat. Both the Army and Air Force operated their own frequency management school. From a user perspective this made sense. The services have different missions, and each use the EM spectrum in a manner to accomplish its own unique mission. Given the size of the Army and the large number of frequencies required by users at different levels, the Army favored a decentralized approach to EM spectrum use and management emphasizing control at the lowest possible level. The Air Force favored a more centralized approach to use and management. Each of the services operated their own spectrum management activities. There was no coherent DOD policy. The Joint Spectrum Center, tasked with establishing joint standards within the DOD, was not established until 1994 (Robinson 1997, 55).

Spectrum use and management within the DOD has traditionally taken a back seat to other programs. As stated earlier, until the 1980's, the EM spectrum was essentially viewed as air. Spectrum was readily available. No one owned the EM spectrum. Additionally, certain segments of the EM spectrum were dedicated solely to DOD's use.

Illegal spectrum use, while not encouraged, was condoned by commanders in the field. DOD users at all levels were largely ignorant of the importance of the EM spectrum. The spectrum auctions were a wake-up call within DOD.

Private industry had also voiced concern that DOD agencies had been very inefficient in their use of the EM spectrum. In a February 1997 *Signal* magazine article, Cindy Raiford, who serves as an Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASDC3I), asserts that a great many myths exist in private industry about DOD spectrum use. According to Ms. Raiford, "there are no large pools of unused spectrum reserved exclusively for the services" (Robinson 1997, 55).

Figure 3 illustrates how the three services use the EM spectrum. Each of the services voiced concerns about the auctions. However, the DOD failed to draft a coherent strategy to defend portions of the EM spectrum allocated for its use. Few within the DOD understood the full implications of the auctions. Initially, it was thought that the auctions would be limited to new parts of the spectrum. However, the early success of the auctions forced policy makers to examine other parts of spectrum for possible auction. In late1995, the FCC requested the NTIA look for additional spectrum that could be transferred to the FCC. As the biggest user of government spectrum, the DOD bore the brunt of this transfer. By the end of 1998, over 255 MHz of previously DOD owned spectrum, had been reallocated to the FCC for possible auction (NTIA, 1998). The problem is especially acute for the Army.

Figure 3 shows the spectrum requirements of an Army Division. The Army hopes to leverage technology and information. A key component of the Army's digitization effort is control of the EM spectrum. As this study will show, the Army has placed

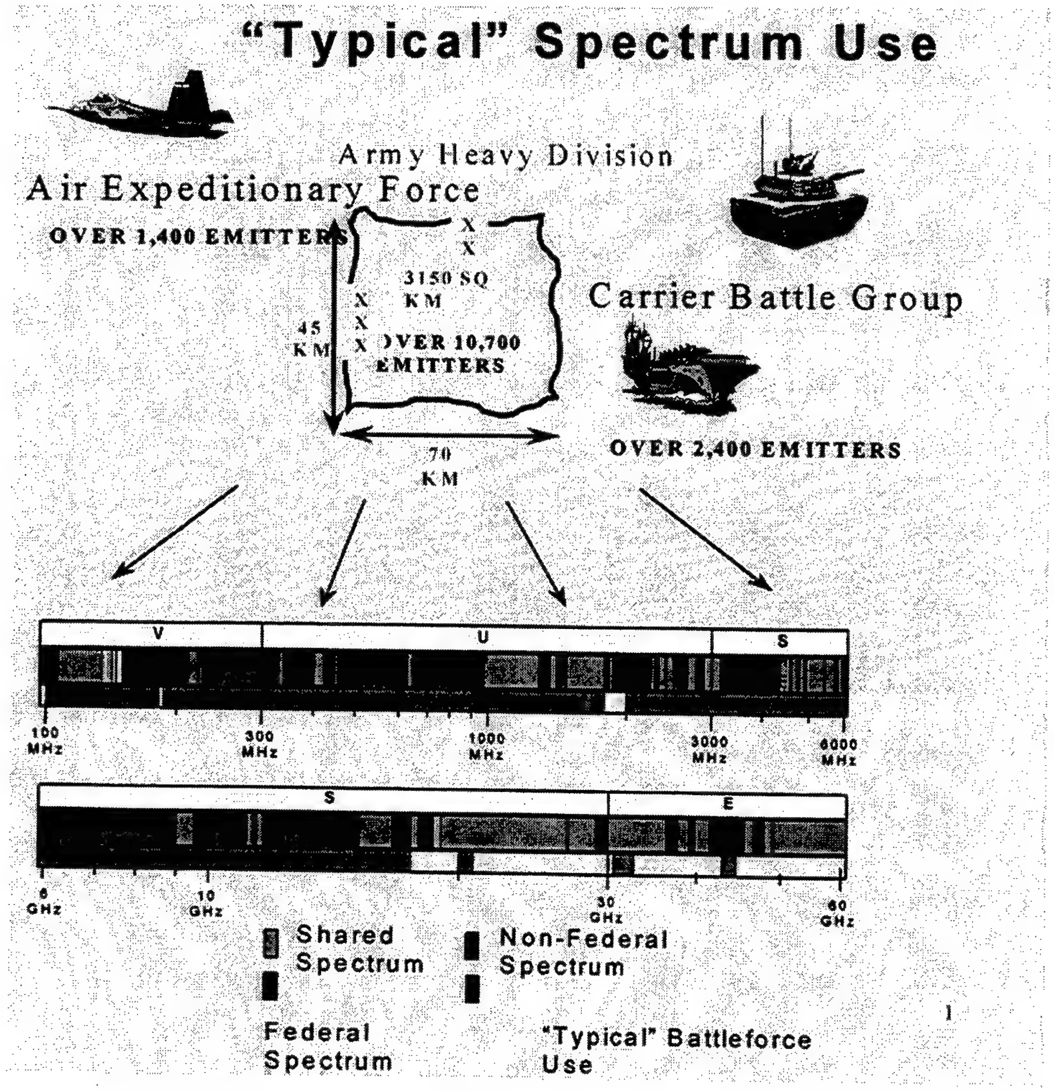

Figure 3 (Source: Joint Spectrum Center, 1999)

tremendous emphasis on information and emerging technologies. The digitized division will have fewer soldiers and fewer weapons systems. Logistics will be forward focused. Fewer artillery rounds will be needed to destroy enemy systems. The digitized division will be extremely dependent upon information and more importantly, the ability to move information quickly around the battlefield. Additionally, precision guidance systems and navigation systems of the future may require use of spectrum in bands that have been

auctioned. New technology may find that certain portions of the EM spectrum are especially well suited for mine detection equipment. Wireless local area networks (LANS) used to connect a fast-moving mechanized brigade tactical operations center (TOC) may operate in bands allocated to industry.

The many posts and stations around the world will also be greatly impacted by the auctions. Very often a post may be located in an urban or heavily developed area. Posts and camps are constantly looking at ways of reducing cost. Future posts Directorate of information management (DOIM) may have to pay for spectrum use for systems such as wireless LANs. Military Police and other users may pay for the use of land mobile radio systems. Already at some posts, such as Fort Hood, planned cellular phone systems require payment to private vendors for use on or around posts.

Future auctions pose serious questions for the DOD. The FCC is now considering, for auction, frequencies for use in emerging technologies. In many cases, these technologies, like millimeter wave radio, are in the very early stages of development. Given the pace of technological advancements in the telecommunications industry, it is difficult to predict the future. What bands in the future will the military need for command and control? Military planners may find themselves closed out of critical systems before they are developed.

Satellites have become a critical part of military operations. There are no multichannel satellite bands set aside specifically for military use. These bands are shared. During NATO's peacekeeping operation in the Balkans, a frequency coordination cell was established to coordinate frequency use during the operation. The cell coordinated frequency use in Croatia and Bosnia. The North Atlantic Treaty

Organization's (NATO) peace Implementation Force (IFOR) use of multi-channel satellite systems was greatly limited due to objections by national authorities in the above mentioned nations. On several occasions, national telecommunications officials requested payment for use of certain frequencies. Defense planners increasingly must rely on civilian systems. Existing satellite spectrum bands have become very congested. New satellite systems use higher frequency bands. At a recent, World Radio Conference (WRC), these bands were discussed for possible auctions. Table 1 lists some of the bands identified for reallocation to the Federal Communications Commission:

Table 1. Spectrum Constraints Imposed by Recent and Planned Reallocations

Band Affected (MHz)	OBRA-93, Title VI	BBA-97, Title III	MHz Reallocated	Reallocation Status
138-144		139-140.5	1.5	Mixed
		141.5-143	1.5	Mixed
216-220		216-220	4	Mixed
1350-1400		1385-1390	5	Exclusive
	1390-1400		10	Exclusive
1427-1435	1427-1432		5	Exclusive
		1432-1435	3	Mixed
1670-1690	1670-1675		5	Mixed
1710-1850	1710-1755		45	Mixed
2300-2310	2300-2310		10	Exclusive
2310-2390		2385-2390	5	Exclusive
2390-2450	2390-2417		27	Exclusive
	2417-2450		33	Mixed
3600-3700	3650-3700		50	Mixed
4500-4800	4635-4685		50	Exclusive
Total MHz Reallocated	**235**	**20**	**255**	

(Source: *US Army Spectrum Management Study* 1998)

CHAPTER 2

LITERATURE REVIEW

> The military is also facing a new challenge from the commercial and international sectors over an issue no one anticipated 20 years ago: availability of the frequency spectrum. In the rush to provide bandwidth . . . it is critical that future spectrum sales take the impact of defense systems into account. There is potentially a significant dollar impact involved in this issue. If DOD has to yield portions of the spectrum to new commerce, existing military equipment must be replaced with systems that can operate on other portions of the spectrum. GEN Hugh Shelton, CJCS testifying before the House Committee on National Security. (GAO 1997, 9)

Over the past decade, there has been a tremendous amount of information published on the need for auctions, the auctions themselves, the industry response, and worldwide impact of the auctions. Although far fewer in number, several articles have been published on the impact of the auctions on the DOD. To properly cover this topic and limit its scope, this study will examine key articles. The literature review will be broken into four areas: internet sources, nongovernment publications, government publications, trade publications.

Given the large amount of information published on the auctions, this study will not attempt to examine all information available but instead will focus only on the information that was used extensively for this study.

Internet Sources

In conducting this study, the Internet was an extremely valuable resource. Given the large number of web sites used, all web sites will not be listed. Given the incredible pace at which the communications industry is developing, the internet provides the most up-to-date source of information. The amount of information available on this topic was almost overwhelming. Using Yahoo or other search engines, it was very easy to find

information on the many associated topics used for this study. Only the web sites that provided the most useful amount of information will be discussed here.

The FCC, NTIA, Joint Spectrum Center (JSC), the Army Signal Center and the Army Digitization Office (ADO) web sites were especially useful. The FCC web site at http://www.fcc.gov is a great starting point to explore spectrum utilization in the private sector. The FCC web site also provides the most comprehensive overview of the use of the EM spectrum. Information explaining the auctions, what portions of the EM spectrum have been auctioned as well as corporations which have bid on portions of the spectrum are listed on the web site. The schedule for future auctions is also listed.

The NTIA web site at http:// www.ntia.doc.gov. provides the best overview of federal government use and management of the EM spectrum. The site also has great information that provides an introduction to EM fundamentals covering such items as modulation and frequency bands. The US National Spectrum requirements document which outlines national spectrum use is available for downloading at the NTIA web page. The site is somewhat limited in its coverage of DOD spectrum use. DOD opposition to the spectrum auctions is not mentioned.

The JSC web site at http://www.jsc.mil provides an overview of DOD use of the spectrum complete with a comprehensive spectrum chart. The JSC web site also provides information on current spectrum projects being conducted at the Joint Spectrum Center.

The Army Digitization Office (ADO) web site at http://ado.army.mil is a great source of information about digitization and the advanced warfighting experiments (AWE). Digitization is an extremely complex issue, and the ADO does an outstanding

job of providing a basic overview of digitization. The web site has several briefings available for downloading. Although spectrum issues are not explored in detail, the web site does provide some information on spectrum issues associated with digitization.

The Signal Center web page at http://www.gordon.army.mil/signal provides information on the Signal Center and on-going projects in the signal and information management communities. The site has draft manuals on line including FM 24-32 *Digitization*, which covers digitization. Major General Cuevillo, the Commander of the Signal center and the Chief of Signal, remarked that given the speed of change in communications, many manuals are outdated by the time they are complete. Having ready access to manuals on line, such as FM 24-32, *Digitization*, was of great use to this study.

Several corporations including McCaw cellular and Sprint have excellent web sites. The McCaw Cellular web site provides a comprehensive overview and explores in detail topics, such as time division multiple access and code division multiple access. An excellent web site that provides tutorials on some of the wireless technologies can be found at http://www.lxe.com/radio.htm. The site guides one through a wireless classroom. The McCaw site is well organized and includes a part covering new and emerging technologies. The McCaw site is very useful for studying wireless technologies. The wireless lab at the University of California at Berkeley also provides detailed information on new and emerging wireless technologies. Other sites including the *Signal* web site and the IEEE web site were also very useful.

Nongovernment Publications

Over the last ten years, thousands of articles in various publications have been written on the spectrum auctions. The many articles in magazines and other sources provide a good overview of the industry in the early stages of the auctions.

Numerous articles in various publications including newspapers, magazines, and trade publications were published in the late eighties and early nineties on the auctions. In early 1993, the *Wall Street Journal* published several articles on the auctions. These articles dealt mostly with the economic aspects of the auctions. A few references to the DOD were found during my research. Industry was extremely excited about the auctions in the early years between 1989 and 1993. The auctions were seen as a needed change given the problems the FCC had faced with allocation. Additionally, articles were published in the *Washington Post* and the *New York Times*. Telecommunications industry journals including *Wireless, COMMNews* and others, published several articles. These publications provide insight into industry's thoughts on the auctions.

Industry Publications

Signal has been a tremendous source of information on the auctions. *Signal*, the official publication of the Armed Forces Communications-Electronics Association, published numerous articles on the auctions including a comprehensive look at the auctions in February, 1995. *Signal* continues to provide great insight on the auctions and the worldwide impact on DOD agencies.

The First Information War published in 1992 highlights the power of information and information warfare. The book is a compilation of articles about communications and information management during Desert Shield and Desert Storm. Several articles

discuss in detail use of the EM spectrum. Though only two of the articles deal specifically with use of the EM spectrum, the book a provides an overview of a major conflict and the overall dependence on the EM spectrum. These articles provide a framework to study the effects of possible loss of EM spectrum to military planners.

Government Publications

To fully appreciate this issue, a thorough understanding of the agencies involved in the process is required. The NTIA's *Manual of Regulations and Procedures for Federal Radio Frequency Management* provides a good overview of spectrum management in the federal government. The Army *Spectrum Management manual* also explains the federal process though not in great detail. Several military manuals have been used in this study. Perhaps, the greatest challenge when using manuals as a source is that many of the manuals are outdated. Communications is a quickly changing and developing industry. Major General Peter Cuveillo, the current Commander of the US Signal Center, said recently that the center is now putting draft on manuals because many are outdated as fast as they are distributed. This is especially true with respect to spectrum issues. Field Manual 100-6, *Information Operations*, provides a good overview of information operations and discusses the role of EM spectrum. The *Army's Spectrum Management* Manual provides guidance for the use of the EM spectrum. Other field manuals include the EUCOM *Spectrum Management.* All of the manuals listed above only briefly discuss the auctions. Given the political nature of the auctions, it is unlikely that military publications will address this issue in any detail. The *Final Spectrum Reallocation Report*, published by the NTIA in 1993, provides a detailed analysis of early efforts to reallocate spectrum from government users to private industry.

In June 1995, Major Keith June wrote a four-page article that was published in the *Army Communicator*. The article provides a basic overview of the FCC auctions. Since then, several other pieces have been written on the auctions and their possible effect on the military including one by the Army Spectrum Manager Frank Holderness. The Armed Forces Communications Electronics Association (AFCEA) has published several articles in *Signal* magazine on the spectrum auctions and their impact on DOD. Beginning in the early nineties, numerous articles appeared in publications including the *Army Communicator* on the spectrum auctions. By 1996, impact of the auctions was being more closely studied by government agencies including the Congressional Budget Office (CBO).

Joint Vision 2010

The DOD pamphlet, titled *Joint Vision* 2010, provides a visionary framework for DOD in the next decade. Joint Vision 2010 is the DOD strategy for the twentieth-first century. Often abbreviated as JV2010, it is the conceptual template for how America's Armed Forces will channel the vitality and innovation of people and leverage technological opportunities to achieve new levels of effectiveness in warfighting (DOD 1997, 1). JV 2010 examines five areas in an attempt to focus the efforts of the Armed Forces as it prepares for the twentieth-first century. Those "Dynamic Areas" are enhanced jointness, multinational operations, information superiority, technological advances, and potential adversaries.

JV2010 illustrates the acceleration in technological change. It states that "successful adaptation of new and improved technologies may provide great increases in specific capabilities" (DOD 1997, 11). Throughout the document are references to

advances in areas, such as electromagnetic technology, global positioning, enhanced stand-off, and precision delivery systems. *JV 2010* states that "The combination of these technology trends will provide an order of magnitude improvement in lethality.

Figure 4 shows the relationship between information superiority and the other tenets of JV 2010. As stated earlier, information superiority is identified as a key element of JV 2010. *JV 2010* states "We must have information superiority: the capability to collect, process, and disseminate an interrupted flow of information while exploiting or denying an adversary's ability to do the same." New command and control systems are also discussed in *JV 2010*. JV 2010 identifies four new operational concepts: dominant maneuver, precision engagement, full dimensional protection, and focused logistics (DOD 1997, 19). Clearly, information superiority will be the glue that combines these new tenets.

Exploiting these new technological innovations will require a great leap forward in command and control systems. *JV 2010* states that, "The basis for framework is found in improved command and control, intelligence which can be assured by information superiority" (DOD 1997, 14). The future battlefield will be more dynamic, more joint, more lethal and more information based. Commanders will be forced to rely more on technology. The joint task force of the future will have fewer but more precise weapons systems. Gone already are the days of large stockpiles of supplies, instead logistics will be focused on getting the right part where and when needed. JV2010 addresses information and technology more than any topic. DOD's ability to fight in the next century is fundamentally based on its ability to harness technology and information.

Both are based on access to and extensive use of the EM spectrum. Spectrum availability will have major impacts on both information superiority and technological advances.

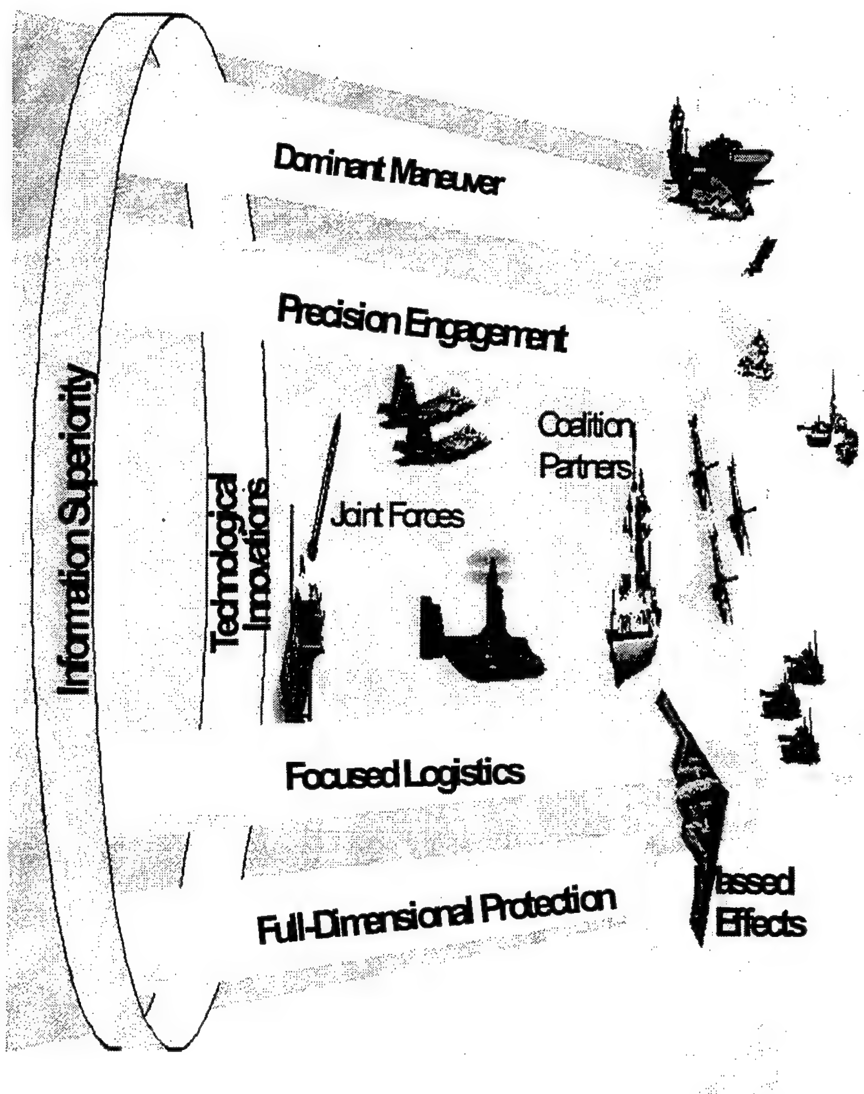

Figure 4. JV2010 and Information Superiority (Source: *Joint Vision 2010* 1997, 3)

The Government Accounting Office Report

In June 1997, the Government Accounting Office (GAO) published a study focusing on the auctions and their possible impact on the DOD. The study titled *Defense Communications: Federal Frequency Spectrum sale could impair Military Operations* examined the auctions from several perspectives. Though broad in nature, the study did examine several specific programs, such as the Navy's $3 billion Cooperative Engagement Program (CEP) and the Army's Digitization Program. The study also examined what steps the DOD, Department of Commerce, and the FCC could take to minimize possible disruption to the DOD (GAO 1997, 1). In 1993, the DOD did not concur with the transfer of government spectrum to the FCC but eventually did acquiesced to the transfer. Since 1993, the DOD had expressed specific concerns about certain bands being transferred to the FCC.

As part of the 1993 Omnibus Budget Reconciliation Act (OBRA), federal agencies were required to provide a span of frequencies not less than 200 MHz for allocation to the public (GAO 1997, 4). The stated intent of the transfer was to promote the development of new technologies to serve the public interest. The GAO report acknowledged that lawmakers viewed the auctions as a source of funds to help balance the federal budget. The administration estimated it will receive about $8 billion in auction receipts in fiscal year 1998 (GAO 1997, 4). The OBRA also stated that to minimize possible negative impact on the DOD that any spectrum to be reallocated must not be "required for the present or identifiable future needs of the Federal Government" (GAO 1997, 4). The study recommended a halt in transferring to the FCC certain spectrum bands that were in use by the Navy. Throughout the study, the GAO reported

that the services were unable to provide conclusive information on the impact the auctions might have on training.

The Air Force Frequency Management Agency stated that operational degradation must now be accepted by many systems because no other frequencies are available to replace frequencies that had been reallocated (GAO 1997, 9). Frequencies used at test ranges were a part of the frequencies transferred to the FCC. As a result of this, several new flight system tests have been delayed. The Air Force also expects problems with high power, mobile air defense systems (GAO 1997, 10).

The Army may face the greatest challenge, as spectrum requirements for digitization were not considered during the reallocation. A study was being done by the Army was unavailable at the time the GAO study was completed. Army spectrum requirements may increase greatly as the result of its experience with the 4th Infantry Division and its digitization effort. During the March 1997, 4th Infantry Division advanced warfighter experiment, "The Army obtained sufficient spectrum by special one time arrangements with the FCC and other federal agencies" (GAO 1997, 10).

As stated earlier, the services did not have adequate planning and management in place to assess the full impact of the auctions. DOD could not determine the number of systems that would be impacted by the auctions. As a result, it has been almost impossible for the DOD to determine what the auctions may cost in moving systems to other frequency bands.

The GAO study made several recommendations to the Secretary of Defense. First, the study recommended that there be a focal point for spectrum issues within the DOD. The study criticized the current DOD spectrum administration structure as

disjointed and inadequate at dealing with long-term spectrum issues. The study stated that often members of DOD involved in spectrum activities were unaware of many aspects of the auctions, such as possible international challenges (GAO 1997, 22).

Second, the study requested that the FCC and Congress examine the results of the DOD study before any further auctions or reallocation take place. It further stated that the 50 MHz that had been transferred in 1997 not be auctioned until more studies could be conducted (GAO 1997, 22).

Third, the study recommended that the FCC and the military agencies share information. This might lower the chances of interference and increase opportunities for spectrum sharing. The report recommended the submission of a joint report involving the FCC, departments of Commerce and Defense, and members of industry. This might help to resolve any issues identified (GAO 1997, 22).

The study also made several recommendations to the National Security Council. These recommendations included a review of the report to the Secretary of Defense for possible national security implications, and a recommendation to the President to determine if the 50 MHz transferred to the FCC should be recovered for continued DOD use.

The GAO study ended by stating that the problems discussed in the report could be a prelude to more problems in the future. The GAO study is the best source of information published by the Government on the auctions and the possible impact on DOD operations. Although very limited in scope, the study identified several major issues faced by the Department of Defense.

Conclusion

Given the tremendous amount of information available on this topic it is critical that the scope be limited and well defined. This study will attempt to look specifically at DOD with respect to Joint Vision 2010.

Spectrum auctions represent a great change in how the federal government manages and regulates use of the EM. How this change will affect DOD is a critical question. This change in government policy may severely hinder the services' ability to execute military missions both within and outside the US.

CHAPTER 3

THE POSSIBLE IMPACT ON CURRENT AND FUTURE SYSTEMS

The reader is aware of the complex nature of spectrum use throughout the DOD and in private industry. The fundamental question is, How will the DOD be able to execute JV 2010 with the continued sale of the spectrum to the private sector? Although JV2010 looks well forward into the twentieth-first century, many systems in current operation will continue to be used into the next century. To explore this issue in detail, some examination of current systems as well as future systems is required. This chapter will demonstrate by looking at the present and the future, that the auctions will impact systems currently in operation as well as future systems. The systems examined here represent only a small portion of one service's piece of JV 2010.

By carefully examining two systems, it is possible to extrapolate some of the problems that the DOD may face across the services. First, this study will approach this issue by looking at the MSE or the tactical radio relay Band IV which operates in the 1350 to 1850 MHz range. This frequency band was identified for reallocation by OBRA 97 and is currently under consideration for possible transfer to the FCC for auction. The second part of the study will be an examination of the Army's digitization effort. Digitization and Task Force XXI are the Army's piece of JV 2010. By examining digitization it is possible to show what impact the auctions will have on one service's attempt to harness information and information technology. Table 2 shows the digitization frequency bands most affected by the auctions.

Table 2. Frequency bands used by Digitization systems most affected by the FCC auctions	
System	Frequency Band(MHz)
Radio Relay Band IV	1350-1850
EAC DGM	1350-1850
ELPRS	225-400
NTDR	225-400
SINCGARS	30-88

(Source: Army Spectrum management Office, 1998)

Radio Relay Band IV

As stated earlier, certain frequency bands are ideal for certain functions. The physics of propagation make the frequencies in the band between 1350-1850 MHz ideally suited for carrying large amounts of information. Additionally, the power requirements are manageable for smaller mobile systems such as those used by the Army. The Army uses this frequency band for its radio relay or mobile subscriber equipment (MSE) Band IV. Band IV is also used by other communications networks, such as those found at Echelon Above Corps level (EAC). MSE provides area common user service at the corps and division level. Although fielded primarily as a voice network in the late eighties, MSE has evolved into the Army's main tactical data pipeline. MSE operates primarily in two Bands: Band I and Band IV. Band I is in the area between 225 MHz and 400 MHz. Band IV provides much greater information capacity than Band I. EAC units are even more dependent upon Band IV. Given the large information requirements of EAC units, these units use this band along with satellite systems almost exclusively for terrestrial backbone connectivity. Radio Relay Band IV lies at the heart of Army communications

systems from Division to EAC. Although both bands have been under consideration for possible transfer to the FCC for auction, this study will look at Band IV to determine the possible implications if this band is lost.

MSE Band IV provides connectivity for the backbone system links both in the MSE and EAC networks. A good analogy with the civilian world would be connectivity between large urban areas. The large pipes that provide voice, data, imagery, and other information to corps and division elements use Band IV. Without Band IV, Army units would face tremendous problems in both voice and data connectivity. Given the Army's move toward using more information systems, loss of this frequency band would greatly hinder operations. Loss of access to this portion of the spectrum would cause several problems for the Army especially at the division and corps levels.

Loss of this band would create several challenges for the Army. First, relocating to other portions of the spectrum will be extremely difficult for several reasons. As this study has demonstrated, open spectrum is at a premium. Given the information carrying capacity of the frequencies between 1 to 3 GHz, some refer to this band as beachfront property. Industry welcomes access to this band. Additionally, portions of the spectrum that are available for use are less suited to move the information rates currently transmitted in this band.

Assuming one could move to another portion of the spectrum, relocation to other frequency bands also creates other challenges. Legacy systems, older less flexible systems, will require major modifications involving replacing crystals, circulators and filters. These parts are critical to radio systems functioning properly. Some software and other hardware modifications would also be required. In some cases, older legacy

systems cannot be modified. In these cases, new equipment would have to be designed and fielded. New equipment would create many logistical and training issues. Existing test and repair equipment might require modifications.

Additionally, relocation to other bands could change transmission characteristics affecting communications planners. Movement to other bands will also require extensive propagation studies. The impact on other bands must be considered as relocation to other bands might also create interference in adjacent bands for military or civilian users.

The estimated cost of relocation for this band for Army communications equipment alone is estimated at $525 million. A move to another frequency band is estimated to take some five years to complete (*Army Spectrum Management Study* 1998, 12). Again, this is the cost of Army communications equipment in one band. The Army is quite concerned about the possible loss of this band and has petitioned Congress through the NTIA for a reexamination of possible transfer.

In summary, loss of the 1350 to1850 frequency band will present several challenges for the Army including possible relocation to another frequency band offering the same degree of capacity, significant cost, equipment modifications and training issues.

Digitization

> Internally, the command and control company includes the communications elements necessary to link the command group horizontally and vertically with other JTF components. This means communications consisting of Ultra-High Frequency, Super High Frequency, Very high frequency and high frequency radio. Internally, digital systems can transit this information to subordinate elements. (Macgregor, *Breaking the Phalanx* 1997, 72)

Douglas Macgregor's book, *Breaking the Phalanx*, provides a great illustration as to how Army units may look in the future. The future strike force, discussed in breaking the Phalanx, gives the reader some idea of how the Army will fight future wars. Task Force XXI is the Army's official vision of the future and is the US Army's portion of JV 2010. The heart of Task Force XXI is the Army's digitization effort. Task Force XXI is heavily dependent upon information and information technology. The Army hopes to leverage information and emerging technology to create a force that is smaller, lighter, but more lethal. The infantry battalion of the future may have more computers than rifles. Information and the ability to move information quickly is the key to the Army's future. As with all parts of JV 2010, access to, and control of, the EM Spectrum is a key component of the Army's new strategy. One should recognize that digitization is more than one system but a long-term strategy with several components.

The Army Digitization Office (ADO) defines digitization "as applying information technologies to acquire, exchange and employ timely information throughout the battlespace . . . tailored to the needs of each decipher (commander), shooter, and supported, allowing each to maintain a clear and accurate vision of his battlespace necessary to support both planning and execution" (Army Digitization office Digitization, 1999).

Few realize that digitization started with the fielding of the Army tactical command and control system in the early eighties (GAO 1996, 26). However, the budget reductions of the early nineties forced the Army to accelerate its digitization effort. Digitization is an incredibly complex issue that could easily consume several studies. This study will define digitization, illustrate some of the new concepts and systems that

digitization will employ and briefly demonstrate how these systems will use the EM spectrum and show how the auctions may impact the EM spectrum bands that digitization may employ.

Figure 5 illustrates the dynamics of digitization on the battlefield. What is digitization? As part of Task Force XXI, digitization will greatly change all areas of the Army from maneuver forces to logistics. Gone are the days of stockpiling parts and ammunition. Smaller logistical sites will replace the huge logistical stockpiles created during Desert Storm. Future logistical systems will be based upon user demand, that is, the right part at the right place and time. Map boards and other graphics will be automatically sent from battalion to brigade to division. In an effort to reduce fratricide, situational awareness, or knowing your location, friendly locations and enemy locations are a key component of digitization. Maneuver, command and control, and logistics will all use digitized systems that will be closely integrated.

The Army's goal is to exploit state-of- the-art communications, sensors, space-based resources and computing systems to provide a commander with a decisive edge over any adversary. Of course, these systems are greatly dependent upon the success of information systems.

The Army Digitization office provides five broad capabilities for the digitized battlefield. Those categories are integrated battle command from platoon to corps, relevant common picture of battlespace at each level, joint and multinational interoperability at appropriate echelons, more responsive logistics within and between theaters, and enabling smaller units to be more lethal and survivable.

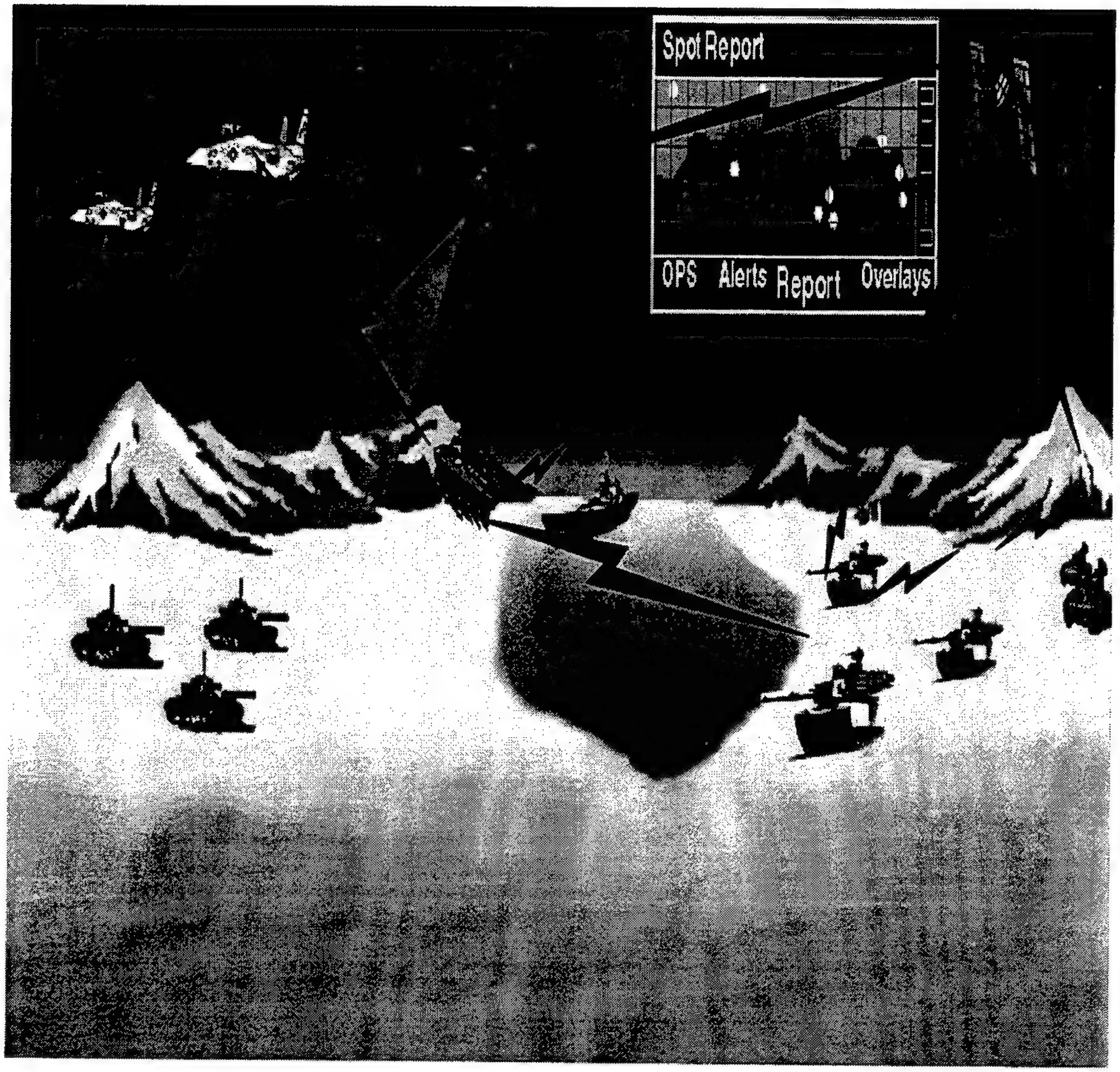

Figure 5. Battlefield Digitization. (Source: Army DigitizationOffice, 14 January 1999)

Each of the aforementioned areas rests upon an information system or systems. These systems include the all source analysis system (ASAS), maneuver control system (MCS), and combat service support control system (CSSCS). Over fifty systems will be integrated into the digitized battlefield. Video teleconferencing (VTC), targeting information and intelligence information are but a few of the critical pieces of information that will ride information pipes. Each system supports some functional area,

such as intelligence, maneuver or logistics. Of critical importance to the Army and this study is how these systems will interface and exchange information.

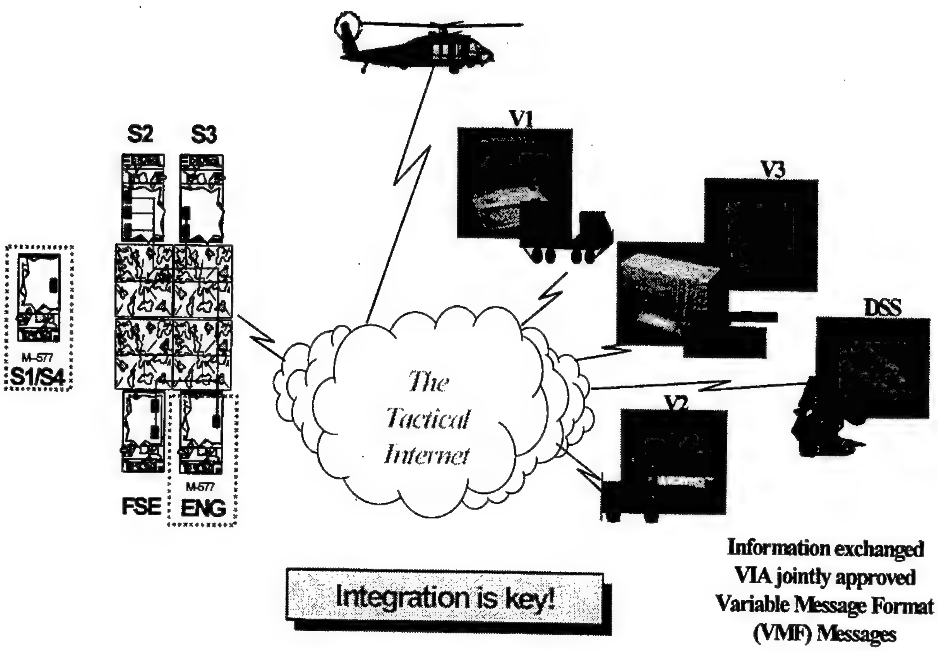

Figure 6. Tactical Internet Connectivity. (Source: Army Digitization Office, January, 1999, 4.)

Figure 6 shows how the various parts of the TI will interface. Bandwidth requirements have grown greatly as the result of digitization. By bandwidth we mean the amount of information that must be moved across the battlefield. The AWE identified limited bandwidth as a major shortcoming in the Army's digitization effort. Digitization will place tremendous demands upon the spectrum in several areas. Perhaps the three

areas most vulnerable to loss of spectrum access in digitization are the area common user system, the Tactical Internet, and the enhanced position and location system (ELPRS).

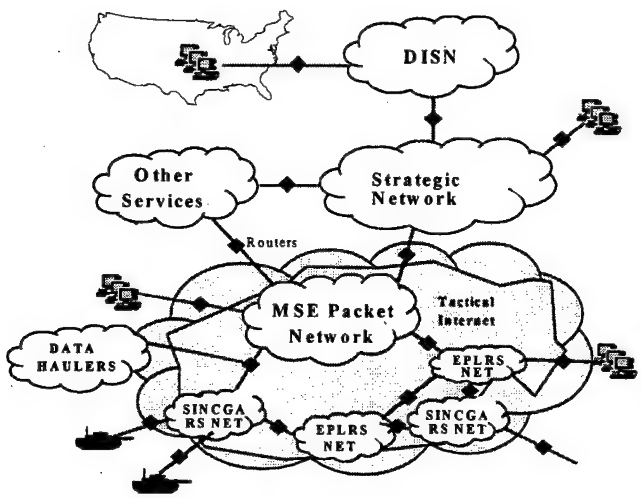

Figure 7. The Tactical Internet.(Source: Army Digitization Office, January 1997)

A key component of digitization is the Tactical Internet (TI). Figure 7 illustrates TI connectivity and the importance of integrating the different systems on a digital battlefield. The tactical internet takes current information technology and applies it directly to the battlefield. FM 24-32, *Tactical Internet*, provides an excellent overview of the tactical internet and is available at the Army Signal Center homepage. The tactical internet will connect the pieces of the digitized brigade, division or corps. It is the glue of digitization. It will provide connectivity for the battlefield operating systems (BOS) using whatever medium is available to pass information. This might include tactical

radio (SINCGARS), the enhanced position and location system (EPLRS), the warfighter information network (WIN), the new joint tactical radio system (JTRS) or satellites. The TI will enable an operator at any level to send information anywhere around the battlefield or for that matter around the world. All of the systems mentioned above use some portion of the EM spectrum. Again, the goal of this study is to provide an overview to demonstrate the demands placed upon the EM spectrum.

Digitization at least for the foreseeable future, will use an advanced version of the mobile subscriber equipment (MSE) system called enhanced MSE (EMSE) as its area common user terrestrial system, that is, the telephone system. However, MSE was designed primarily as voice network and has proven incapable of handling the large data requirements required by digitization. MSE will be significantly upgraded to move the large amounts of data required by digitization. Enhanced MSE will be similar to the current MSE system except for data capability. The pipes required to move information on the digitized battlefield must be much larger. Moving the large amounts of information required to support digitization will require several changes to MSE. Chief among these changes will be more use of MSE Band IV. Digitization data transmissions will require more radio relay systems to use Band IV. Future radio systems with even greater data capability are being planned.

MSE currently operates in two bands. These bands have already been restricted to some degree. Private industry also has great use for these bands. The AWE identified limited bandwidth as a major shortcoming of the digitization so future MSE systems will need to use more Band IV frequencies instead of Band I. As discussed earlier, Band IV is under consideration for transfer to the FCC for auction. Greater use of Band IV in the

digitized force has several implications. First, given the increased use of information systems, the bandwidth requirement will be greater. Additionally, fewer frequencies will be available in a given frequency band. Losing complete access to this band or further restrictions could greatly reduce the ability of a division or corps to move information.

A second component of the TI is moving information across tactical radio nets and EPLRS. Currently, the Army uses SINCGARS as its tactical radio system. EPLRS and SINCGARS are envisioned as the center of the TI at the brigade and battalion. SINCGARS along with ELPRS will serve as data link at the tactical level. SINCGARS operates in the 30 to 88 MHz band. Given the relative low frequency of this band, it is not ideally suited to move large amounts of information. Although fielded as a position and location system, ELPRS will be the Army's primary data links at the tactical level. Until newer systems are fielded, EPLRS will continue to be the Army's data links for the foreseeable future. ELPRS will operate around 400 MHz, a band that is being considered for auction. 400 MHz is the key component for data connectivity at division and below.

The long range plan for data at the battalion and brigade is the near term digital radio (NTDR) which will also operate around 400 MHz. NTDR is being designed to transmit digital information. Another new system is the inter-vehicular wireless data transfer system will, operate around 400 MHz. Again it will operate in an already congested and contested band.

The future spectrum requirements for the digitized battalion and brigade will be very large. The Army will continue to operate SINGARS, EPLRS, and MSE. New systems, such as the NTDR will be fielded in the next decade. All of these systems operate in three bands: 30-88MHz, 225-400 MHz, and 1350-1850MHz. Attempting to

determine the frequency requirements for a digitized battalion or brigade is extremely difficult given the move to wireless systems. Conservative estimates put the number of frequencies required for a typical digitized battalion at more than 600. However, if a typical brigade based on the AWE is examined, frequency requirements are estimated at 4,100 frequencies (General Accounting Office 1997, 20). This number includes systems outside the bands discussed above however; most of the systems in use by a digitized brigade lie in 1350 to 850MHz or 225 to 400 MHz.

Conclusion

Digitization has many components. Perhaps the most important part of digitization lies in communications or connectivity. The physics of propagation forces the Army to operate in certain bands. With Task Force XXI, these bands become increasingly congested. The two most critical bands that digitization will rely upon for communications are 225 to 400 MHz and 1350 to 1850 MHz. Both bands are being considered for possible auction with great consequences for the Army's digitization effort. The impact of losing total access to these bands will result in forces across a brigade or battalion not being able to send information around the battlefield. Moving information is key to the Army's digitization efforts. Without being able to link the many information systems at the Brigade and battalion level, tactical commanders will be at a decisive disadvantage in any future conflict.

CHAPTER 4

POSSIBLE SOLUTIONS

The previous chapter identified some of the issues associated with the auctions and their possible impact on DOD activities both now and in the future. As DOD looks at declining budgets and manpower, information and information systems will be more important. Meanwhile, DOD is faced with limited access to the EM spectrum in the future. DOD must do more with less with regard to spectrum and other resources. How DOD approaches this complex problem will have long-term impacts beyond JV2010 and digitization. DOD must take steps now to assure continued access to the EM spectrum.

Given the complex nature of the spectrum issue, simple solutions are not possible. Different bands and different systems will require different solutions. How should DOD approach this issue? Many have argued that the auctions themselves are the issue and DOD should work to end the auctions. This approach has several flaws. First, given the revenues already derived from the auctions, it is unlikely that the federal government will end the auctions. As shown earlier, senior government officials see the auctions as a win-win proposition. The auctions will continue for the foreseeable future. Second, many in industry have argued that the DOD has been terribly inefficient in its use of the spectrum. Part of the reason the FCC looked to the DOD for possible open spectrum was the perceived view that DOD was inefficient in its use of the spectrum.

Developing solutions to enable continued military access to spectrum requires innovative approaches from DOD, government, and industry. However, technology may provide the best answer to DOD's spectrum issues. This chapter will explore some of the possible solutions that DOD may use to ensure continued access to spectrum. Some of

the possible solutions are extremely technical and beyond the scope of this study; however, the study will explore some of the new technologies to demonstrate what may be possible. Solutions will be grouped into three areas: technology, government or industry. This is not to say that solutions will fit conveniently into these three areas. However, they do provide a framework as to how DOD may approach solutions.

Technology

Technology offers the best solutions to future spectrum access. This study will demonstrate some of the broad technological approaches that could greatly improve spectrum efficiency. Not all-technical solutions to this problem are new. Much of the information found in researching this chapter was innovative approaches taken by the military in the fifties in designing new radio systems. The cellular phone industry has been in constant search of new ways of getting more use out of each frequency. The industry has been constantly in search of better and more efficient ways of using the EM spectrum and has been at the forefront of developing new and innovative approaches to better spectrum efficiency. The cellular industry has developed methods to allow several users to use one frequency thereby greatly improving spectrum efficiency. These companies are severely limited by the number of available frequencies for use in a given band and area. The problem is especially acute in large urban areas, such as New York or Washington, D.C. Cellular companies have invested in creating new systems to improve spectrum efficiency. Again, some of these innovations are not new. In fact, the Army and the other services have already incorporated many of these technologies into existing radio systems though their use has been greatly limited.

Perhaps the most basic question in this issue is defining spectrum efficiency. In private industry, allowing one user to use one frequency would be seen as terribly inefficient. Allowing one net per frequency as the Army often does would also be seen as inefficient by many in industry.

Spectrum efficiency can be shown in several ways. In analog systems, such tactical radio systems, spectrum efficiency is often shown by the duty cycle or the number of seconds in a given minute that a frequency is used. For most FM frequencies in the Army, this is seven to eight seconds which is very inefficient by industry standards. In digital systems, spectrum efficiency is shown using the number of bits per Hertz (Lee 1997, 319).

Bits are Bits--Moving to a Digital World

The move toward digitization is itself a help in the move toward more spectrum efficient systems. To clarify, when digital systems are discussed, the specific technology of digital systems as opposed to analog systems is discussed. Analog systems can be quite cumbersome. Differing standards and differing systems make analog systems much more difficult to use. To digitize information is to sample information in some manner then convert the information to a series of ones and zeros. This greatly simplifies the digital process but does provide a basic understanding. Digital systems though more complex are simpler in some ways. Digital information can be transmitted using whatever medium is available. Digital systems move information. It does not matter that the information may be video, telemetry, voice, or targeting information. Bits are bits. Digital systems generally require less bandwidth than analog systems to convey the same amount of information (Gibilisco 1999, 98). Digital systems also lend themselves to other

technologies, such as data compression and multiple access systems. Both of these will be explored in more detail later in this chapter. The first step in making DOD systems more spectrum efficient is moving to digital systems.

Digital systems can extend the range of usable frequencies. Analog systems, such as voice or video, can be converted into a digital format. The digital data is then cleaned up so the information can then be transmitted using a digital protocol. By cleaned up, it is that noise and other interference can be eliminated from the transmission. Using this procedure it is possible to better use some frequencies, such as HF, which has been limited due to high noise levels. Digital signal processing has proven itself to be very useful at eliminating noise and other natural phenomena (Gibilisco 1999, 99).

Digital systems are also extremely predictable. The receiver knows what to expect from a transmitting station. The receiver and transmitter can operate in lockstep. This makes it possible to use tools, such as filters, to further eliminate false signals and other possible problems.

Digital systems would also allow the use of data compression. Data compression uses reduced logic bits to convey repeated information. Text and software can be compressed without losing any of the detail but the compression ratio can rarely be greater than two to one. Images are just the opposite. Given the increasing demand for video and images, data compression holds great promise for the future. Some digital images can be compressed as much as twenty to one. Images that might take an hour to transmit without compression could be transmitted in as little as three minutes using compression. Compression is a relatively easy solution that DOD can use to greatly

improve bandwidth. Compression would be especially useful for area common user systems, such as those that use the radio relay Band IV (Gibilisco 1999, 98).

Digital systems would also allow the use of various internet protocol (IP) systems already widely used in information systems. Digitized information is sent via a medium in packets. This creates tremendous possibilities for both information systems and more spectrum efficient communications systems. Packets would be given headers that would contain information that could greatly improve spectrum efficiency. These information packets could be sent using whatever medium is available including FM, AM, radar, or any other medium. Again the focus is on getting information through not on the particular media.

Using multiple access systems, such as TDMA or CDMA, several nets may be placed on one frequency. Packets might also contain security information. The packet headers could identify users and give higher precedence to some users, such as commanders. Information could be compressed thereby also increasing available bandwidth. However, as this study has shown, voice is simply information and as such would be treated like other information, such as imagery or a parts request.

Multiple Access Systems

Two or more signals can occupy the same medium or channel at the same time. This is called multiplexing or multiple access. Various schemes including frequency division multiple access (FDMA) or time division multiple access (TDMA) are used to do this. Newer multiple access systems include code division multiple access (CDMA) and ALOHA. All of these systems allow one frequency or more correctly one channel to

transmit several signals or allow several users to operate on one frequency (Lee 1997, 319).

FDMA is the oldest of the aforementioned systems. FDMA takes one frequency and divides it into several channels. For instance a 25 kHz channel may be divided into five 5 kHz channels. Though an analog system, FDMA has been used for several decades. However, its use in the US military has mostly been for multichannel systems in the UHF and SHF range. Multiple Access technology has advanced greatly since the introduction of FDMA. Though an older system, FDMA still is used extensively across the United States and Europe for cellular systems.

TDMA and CDMA are two of the newer systems in use today. Both TDMA and CDMA use digital technology. In TDMA, a given channel is divided into time slots thus a given channel or frequency may be divided into many time slots. Each slot would then represent a particular net. TDMA greatly improves signal efficiency. CDMA uses an even more radical approach to divide a given frequency. In CDMA, each conversation or net is assigned a code. This access scheme allows several users to use the same frequency at the same time. These codes, called pseudo-random code sequence, are based upon a complex mathematical model. The codes are used by mobile stations to distinguish between calls. CDMA cellular networks are currently being built around the US. CDMA technology improves bandwidth capacity sevenfold (CDMA, TDMA 1999). All of these technologies could greatly improve spectrum efficiency for DOD systems especially systems operating below 3 GHz.

Some systems, such as the European cellular system, the global system for mobile communications (GSM), use several access schemes. GSM is often called an analog-

digital hybrid because it combines both analog and digital systems. GSM incorporates FDMA to divide a frequency into several channels then uses TDMA to divide the channels. Given the population density and tremendous cell phone usage in Europe, GSM has been very spectrum efficient.

A future maneuver brigade radio network might use digital radios to transmit information. These radios might use TDMA or CDMA technology. One frequency, or its equivalent using a hopping system, could be used to transmit all of the brigade nets which often require more than four frequencies. Each net could be given a time slot. Information from a given user would be sent in packets containing information about precedence, security and location. The packets might also contain error correction information to ensure that even if some bits were missing due to noise of jamming, the information would still reach the distant end. Additionally, using data compression, information currently being sent over MSE Band I or Band IV frequencies could be sent over SINCGARS or NTDR.

Digital systems could greatly improve spectrum efficiency and help DOD maintain access to critical spectrum. Digital systems use less bandwidth, improve overall system performance, and avail themselves more easily to other technologies such as data compression. Digital systems are but the tip of the iceberg in future wireless systems.

Smart Radios

As part of this study, Frank Holderness, a Defense Information Systems Agency (DISA) senior executive, was interviewed. Mr. Holderness currently serves as the DISA coordinator for spectrum utilization in the DOD. Previously, Mr. Holderness served as the Army Spectrum Manager for six years. During the course of our conversation, Mr.

Holderness discussed several times the concept of a smart radio, a radio that could as he put it sniff the air in search of open frequencies (Mr. Holderness, 1999). Smart radios are no longer in the realm of science fiction. Although not officially considered a smart radio, NTDR is seen as the first in a series of radios that will revolutionize radios throughout the DOD.

Smart radios are one of the names used to describe the radios of the future. Another name used to describe this new family of radios is software radios. Smart radios are radios that will operate in several bands, manage their own frequencies, modulate using different modulation schemes, and could be used for many different functions, such as communications, radar, or as sensors. These radios will be multimode, multifunction, multiband and much more spectrum efficient (Kalle Knutson, 1999). Additionally these systems will be adaptive or smart enough to take advantage of free or open spectrum and where possible use other networks such as an existing GSM or satellite network. These smart radios would have embedded microprocessors that would allow a user to program special uses for a given system.

The smart radio could use the GPS to determine its location and then consult a database of frequencies. The radio would then sample or sniff the air and determine which bands were in use and where open spectrum was available. These radios could continuously monitor the airwaves and move to open spectrum as bands became saturated. These radios might not transmit on one frequency but using spread-spectrum technology transmit over a range of frequencies using digital technology to ensure that the information reached the distant end. Such a system would transmit just above the

noise level allowing more users across a given band. The user could change the radio's function by changing the software.

These radios or radio systems are not as far away as one might expect. Again the cellular telephone industry already markets cell phones that can use several cellular systems including those in use in the US and Europe. Currently, there are three cell phone systems in use in the US. Given the differing frequency allocation bands in use in Europe and the US, these systems are also multi-band. The Iridium handset, built by Motorola, can up link directly to satellites or use an existing cell phone network, such as GSM. The handset is smart enough to know if an existing network is available.

Both the new Near Term Digital Radio and the JTRS are considered by many to be the smart radios of the future. The systems are designed to be used by all services. The JTRS will operate across several bands from HF through UHF. Currently the greatest technical problem facing the radio is antenna technology (Kalle Knutson, 1999). Smart radios could greatly change the spectrum debate. Smart radios might use whatever spectrum is available in any band to transmit information including HF, VHF, UHF, or even EHF.

Part of the problem in the spectrum issues is the fixation on individual frequencies. If systems can be designed that will operate in several different bands, then utilization could be greatly improved. Smart radios present another possible solution that is being explored by future communications planners. In the future, if smart radios can operate in several bands, why not use any band to transmit information? If a particular radar band is not is use, why not use this band to transmit information. To many this sounds like a radical proposal, but again, bits are bits. Analog systems were more

susceptible to problems in certain bands. Digital systems are far less susceptible to noise or interference. Allowing information to be transmitted wherever possible would greatly improve the spectrum efficiency of DOD systems.

As stated earlier, higher frequencies are of limited value given the cost to develop technologies to fully utilize these frequencies. However, several companies have done pioneering work in bands such as millimeter wave. Millimeter wave is above 35 GHz. Several companies have already developed systems that can use these extremely high frequencies. Millimeter wave systems have proven ideal for microcells. The microcells would operate similar to cell phone systems transmitting information either to another cell or to a switched network. These waves do not propagate very far and as such would cause little interference to other systems. Microcells could be established around a division tactical operations center (TOC). Such systems might be ideal for TOC or as vehicular communications system.

Technical solutions really challenge a fundamental issue in spectrum utilization, that being the concept of spectrum allocations. If any band can be used to transmit information, should bands still be allocated only for particular functions? Or can a move be made to a more broad method of spectrum allocation? Moving away from the idea of allocations would allow any band to be use for many purposes, thereby greatly improving DOD's access to spectrum.

Digitization, smart radios, and moving to other bands can greatly improve DOD spectrum efficiency. Quite simply, DOD must squeeze every available bit from every possible hertz. By better using what is available, access can be maintained to key

portions of the spectrum. Additionally, this places the DOD in a much more advantageous position in dealing with industry.

The Steinbrecker Radio

The Steinbrecker radio takes the best of radio engineering and combines it with the best in microprocessor technology. Though designed in the early nineties, the radio has greatly changed the thinking both about radio engineering and spectrum utilization.

The eighties saw a tremendous growth in the communications industry and a corresponding increase in the demand for more frequencies. As stated earlier this was perhaps most felt in the cellular phone industry. The Steinbrecker Corporation looked at this problem and developed a very innovative solution. Instead of devising another multiaccess system, Steinbrecker looked at the radio itself.

The Steinbrecker radio has two great technological innovations. The first is the manner in which the carrier frequency is mixed with information. The second is moving the modulation technique, demodulation method, coding, and channelization away from the radio and into a base station where these functions can be handled through software.

Digital signal processing (DSP) is the process of converting analog signals into digital signals. DSP technology has seen tremendous growth since the early eighties. The key to the Steinbrecker radio is its ability to move a large array of carrier frequencies down to baseband level while avoiding spurious additions (*Forbes* 1994, 84). It is possible to create a radio that could pick up transmission between 30 MHz and 3 GHz; however, such a system would have not be able to clearly distinguish between the information contained in the carrier frequencies. The Steinbrecker radio is able to do just that. This allows the radio to operate in frequency ranges greatly beyond anything

presently possible. Additionally, these radio systems are able to transmit information over a range of carrier frequencies without any loss in signal quality. Essentially the Steinbrecker radio allows the user to transmit information over the full range of carrier frequencies over any group of broadband frequencies. Given the greater frequency range allowed by Steinbrecker technology, it is also possible to send greater amounts of information over a given frequency or channel (Forbes 1994, 84).

McCaw Cellular has designed new digital networks using Steinbrecker technology. Given the broadband capability of the Steinbrecker radio, McCaw designed networks allowing cellular systems to find open spectrum then send information in quick burst across open spectrum. These Steinbreckers radios are true EM sniffers, that constantly scan the EM spectrum looking for open spectrum to pass information. The information is passed using the quickest method possible thereby eliminating or at least reducing the various multiple access schemes currently in use. Steinbrecker technology has improved even more since the early nineties. Current systems handle all modulation types simultaneously. This technology has tremendous possibilities for wireless networks, such as those envisioned for web surfing. These systems have tremendous possibilities for military users.

Government Solutions

Given the explosion in the communications industry, the whole government regulatory structure has been under attack. There have been calls both to eliminate the FCC and the NTIA. However, given the limited scope of this study, changing the regulatory structure will not be examined. As established earlier, the federal government's primary role in this issue has been administrative and regulatory.

At the fundamental level, the federal government must ensure that the DOD has access to required spectrum. As a minimum, the government should encourage and resource the DOD to adopt more spectrum efficient technologies. The government must balance the need to generate additional resources with national defense. However, using national defense as a broad strategy to defend DOD spectrum may not be the best approach to this issue. DOD must look to the future. By continuing to live in the past both in terms of technology and mindset, DOD will remain behind industry in its ability to harness new and emerging technology.

This study has demonstrated that DOD systems could be far more efficient in their use of the spectrum. Several possible government initiatives could help solve the problem. First the government could maintain the current system and not allow any DOD frequencies to be transferred to industry. The current allocation system could be maintained at least for Government users. The federal government could ensure that DOD maintains access to portions of the spectrum deemed necessary for national defense. This solution may be challenged by industry leaders given the perceived success of the auctions. The auctions have proven to themselves to be extremely successful both in generating income for the federal government and as a method of spectrum allocation.

Another government solution might be allowing industry to buy portions of the spectrum but ensuring that DOD be granted access to particular bands. This might be negotiated on a case-by-case basis dependent upon DOD requirements. Government users might be given limited use of certain bands. This would allow a better system of allocation and ensure that government users have access to necessary portions of the spectrum. This might force government users to work more closely with industry users.

An innovative solution being discussed by some in the DOD is to have industry pay to move DOD users out of some bands. Cost associated with this move would be factored into the auction cost. Given the industry desire to move into the 1350 to 1850 band, industry users would pay to move legacy systems from this band to another. This spectrum tax could provide the DOD with the needed resources to move to other bands.

Other solutions might include joint FCC-NTIA-industry panels that look at long-term spectrum use. These panels might establish national spectrum priorities. Although the NTIA attempted such a study, it was limited in scope and had little input from the FCC. This national spectrum discussion might explore possible solutions to ongoing spectrum issues. Given industry innovations over the last decade, industry might help DOD with technical assistance in improving bandwidth. The government could offers tax advantage or auction advantage to industry users willing to offer emerging technology to DOD users.

Industry Solutions

As stated earlier, industry faces many of the same problems as the DOD in facing a large demand but having a limited supply of frequencies. DOD and industry in many cases compete for use in certain bands. In some cases, these bands may be used for the same purpose but by different users. Industry has developed many technical solutions to this problem that have been discussed earlier. What steps can industry take to help DOD in solving this problem outside the technical arena?

Industry and DOD could establish spectrum utilization boards that might examine issues, such as spectrum allocation. Such a system might provide industry with better insight into the problems faced by DOD. Industry members would reach beyond

companies that normally do business with DOD but might instead work with companies, such as McCaw Cellular. The Army Signal Center at Fort. Gordon, Georgia, has embarked on an industry advisory program in information management. As stated earlier, a common perception in industry circles is that DOD has been less than efficient in its use of the spectrum. This might also lessen some of the tension created by auctions.

Frequency Sharing

Frequency sharing could greatly ease spectrum problems both in the near term and long term. This study showed earlier the method by which frequency bands are allocated. Frequency bands are currently allocated for particular use and user. In some cases, bands are shared between industry users and DOD users. In the author's interview with Mr. Frank Holderness, his first comment in regard to future spectrum utilization was the need for more frequency sharing between DOD and private industry (Holderness, 1999).

Many frequency bands are already being shared on a large scale across the US by DOD with industry and with local and state governments. Frequency sharing is not a new concept. However, frequency sharing in the beachfront property bands would represent a great change in DOD practice and policy.

How might such a system work? As opposed to assigning frequency use by band and user, frequency bands might be assigned simply by system, that is, a land mobile radio or fixed. Both government users and industry users might have equal access to a band with government users having sole access during emergencies. Use could be given on a noninterference basis, as is the case for many systems currently in operation. Private users might pay some fee to the DOD on a case-by-case basis to offset any changes that

DOD may be faced to make as a result of greater frequency sharing. Frequency sharing might also ease much of the tension created between DOD and private industry as the result of the auctions.

Frequency sharing would allow much greater use of the spectrum by both DOD and industry. Although DOD would lose exclusive rights to some bands, it would gain use of other bands. Frequency sharing might also work in helping DOD adopt many industry standards.

DOD has opposed frequency sharing on a greater basis for many reasons. Interference and security are perhaps the greatest concern of DOD. If frequency sharing is done in conjunction with other innovations, such as digitization ,some of DOD concerns might be eliminated or at less reduced. Given the tremendous demand for additional spectrum, DOD users will see much more frequency sharing in the future.

Conclusion

There are many possible solutions to DOD spectrum utilization issues. How well DOD looks at the issues and attempts to find solutions in the next few years will greatly determine the course of this debate. The auctions will continue in some form for the foreseeable future. This paper has established the critical importance of DOD's access to the EM spectrum and the need to find innovative solutions

The solutions discussed here are but a few of the many possible answers to the spectrum issue. Solutions may involve technology in the form of multiple access systems, digitization or be administrative in the form of government policy. The solutions discussed here range from using older technologies such as FDMA to more advanced technologies such as the Steinbrecker radio. Solutions may take several forms

and will probably involve technology, industry and government. The GSM system uses both a new technology and an older technology to maximize frequency use. Government may only be part of the solution. As stated earlier, simply using national defense to fend off possible spectrum transfers may be a short sighted policy. What should be clear is that DOD must work closely with industry in attempting to find solutions to this problem.

The future of spectrum utilization is extremely exciting. Private industry is developing many new and innovative approaches to better and more efficient use the EM spectrum. DOD must be at the forefront of helping to develop these new technologies and better use portions of the spectrum that it has access to already. DOD must take a leadership role in developing new approaches to use the EM spectrum. By doing this, DOD can play a much bigger part in the spectrum wars and better determine its own future.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Get the message through!
Early motto of the US Army Signal Corps

This study has demonstrated the tremendous implications posed by the FCC spectrum auctions upon the DOD. The principal research question this study hoped to answer is can the DOD execute JV 2010 with the continued sale of portions of the EM spectrum to private industry. The EM spectrum is an invaluable, but finite national resource. The communications explosion of the eighties created a tremendous increase in the demand for additional frequencies. Faced with this increased demand and a huge budget debt, senior government officials saw auctioning off portions of the EM spectrum as a way of generating much needed federal revenue and as a better method of distributing a limited resource.

As the biggest user in the federal government of the EM spectrum, DOD faces the greatest possible loss in use of the EM spectrum. Private industry saw many DOD systems as inefficient and requested that some of the DOD allocated spectrum be reallocated for possible auction.

The future poses many difficult issues for DOD and our nation in regards to spectrum utilization. The future also poses many great opportunities. Given DOD's increased reliance on information systems, access to the spectrum will be even more critical in the future. As this study has demonstrated, JV 2010 will increase DOD spectrum requirements. DOD must compete with industry for additional access. DOD can execute JV2010 with the continued FCC spectrum auctions. However, this will

require additional resourcing, innovative solutions, and quickly adapting new and emerging technologies. DOD must be on the leading edge of the spectrum utilization debate and work closely with industry to find solutions that will benefit all users.

At the most basic level, DOD must articulate to our national leaders the critical importance of the EM spectrum to DOD systems. During congressional hearings in 1998, GEN Hugh Shelton the Chairman of the Joint Chiefs of staff remarked that, "If DOD has to yield portions of the spectrum to new commerce, existing military equipment must be replaced with systems that can operate on other portions of the spectrum." As this study has shown that will require additional resourcing. However, given General Shelton's testimony, senior leaders in the DOD are aware and concerned about this situation.

Resources and technology are the two major components to solving this problem. Resources will greatly shape this issue in the near and long term. If DOD is able to resource the costs involved in moving to new spectrum bands by adopting new and emerging technologies, then the auctions may not greatly hamper DOD's ability to execute JV 2010.

Technology offers both long and short-term solutions to spectrum utilization problems. DOD must become more spectrum efficient. Digitization alone can make many DOD systems more efficient. Using technologies such as CDMA, data compression and advanced waveforms could also greatly improve the efficiency of DOD systems. This helps to solve two major issues. First, it ensures that spectrum allocated to DOD is better used. As stated earlier, we must get every available bit per hertz. By adopting these technologies, DOD can push more information over existing spectrum

allocations. It may be possible to put some newer systems in existing bands if we can make current frequency bands more efficient. Second it demonstrates to industry that DOD is becoming spectrum efficient. By doing so, DOD becomes more able to influence the future of spectrum utilization in the United States.

A more long-term approach is using smart radios that can find open spectrum. These smart radios must be adaptive, multi-mode, multi-band and able to use flexible networks such as Iridium or GSM. Designing systems with embedded microprocessors that allow users to change functions will also greatly improve spectrum efficiency. The use of Steinbrecker technology will also improve our use of the EM spectrum.

Greater spectrum sharing must be part of any solution. Although greater spectrum sharing poses some questions such as security and interference, DOD must work closely with industry to develop procedures and technologies that will allow greater spectrum sharing. Creating spectrum utilization boards at the national level to enhance the cooperation between DOD and industry could ease some of the tensions created by the auctions. These panels might also look at new and emerging technologies being developed by industry that DOD might take advantage of.

Other government solutions might include the cost of moving DOD systems into the auction price of a particular band. This would provide resources to DOD to help move from some frequency bands and might also deter some companies given the cost involved for some moves. This would also show the public and industry the cost of the auctions to DOD.

Moving to a broader spectrum allocation system that emphasizes information rather that individual frequencies will also make our systems more efficient. New

technology will make some bands previously limited in use due to propagation problems much more useful in the future.

The good news is that DOD is already working on some of the solutions offered during this study. The Army Signal Center is working with contractors on improved waveforms that might improve efficiency. The Joint Tactical Radio System (JTRS), planned for use in the next ten years, is considered by many to be the first of the new smart radios. Though still in the design phase, the radio incorporates many new technologies such as digitization. The Army's Warrior Information Network (WIN) incorporates new technologies at the multichannel level such as compression. Additionally, the Signal Center is examining the possibility of using some satellite frequencies for other uses. Senior officials are aware of the problems the auctions have posed and are taking steps to ensure that DOD maintains access to critical portions of the EM spectrum.

DOD must ensure that it plays a prominent role in helping shape the discussion on spectrum utilization. By working with industry and government, DOD may find some other solutions.

The motto of the Signal Corps is "Get the message through." This motto helps illustrate the paradigm shift that will be required as we move to a wireless world. The most fundamental shift in our thinking must be away from frequency allocation tables and toward information exchange. In the past, technology limited our use of some frequency bands but the future holds great promise that we may be able to send information over a much greater range of frequencies. The Tactical Internet (TI) provides a small glimpse into the future. The TI uses many different systems to transmit

information over a range of frequencies. However, the focus is getting information to the distant end. To many this is a radical thought.

Our fixation on individual frequencies has created an environment where we compete not for information but for frequencies. As we develop smart radios and other technologies that can find open spectrum and quickly pass information over any frequency or at least a much greater range of frequencies, owning particular frequencies will be less important.

This thinking is by no means limited to DOD. The auction themselves are a direct manifestation of this reasoning. By moving away from frequency management to spectrum utilization, we can help to solve many of the issues associated with the auctions and quite possibly the auctions themselves.

The EM spectrum is a natural resource that due to its ability to restore itself at the speed of light is most efficiently used when it is fully occupied. The information revolution has transformed our society. The spectrum auctions represent a fundamental change in how we view the EM spectrum.

JV2010 is DOD's blueprint for the future. It is extremely dependent upon the use of the EM spectrum. DOD can execute JV2010. DOD must adopt new technologies to better manage existing frequencies and future spectrum allocated for its use. How well DOD manages spectrum allocated for its use will greatly shape the future of this debate. Additionally, by working closely with industry on innovative solutions, DOD can assume a leading role in the spectrum issue.

WORKS CITED

1993. FCC Spectrum licenses pending. *Signal,* November 11.

1994. The Steinbrecker radio. *Forbes*, October, 14.

1997. FCC license auction plan appears to backfire. *Wall Street Journal*, 1 August, 12.

Andrews, Edmund L. 1993. Wireless bidders jostle for position. *New York Times*, 5 December, D1.

Army Digitization Office. 1998. Digitization briefing. Washington, DC. Digitization Office homepage. Available from http://www.army. ado. Internet. Accessed 10 January 1999.

Busey, James B., Admiral. 1995. Technology Drives Government Spectrum, *Signal,* February 94.

Campen, Alan D. 1992. *The first information age war*: Fairfax, VA: AFCEA International Press.

McCaw Communications. 1997. TDMA, CDMA, FDMA. CDMA. Berkeley, CA. McCaw Communications homepage. Available from http://www.ee.mtu.edu/courses/ee465/groupe/report/2/3.html9. Internet. Accessed 13 January 1999.

Gibilisco, Stan. 1998. *Handbook of radio and wireless Technology.* New York, NY: McGraw Hill.

Holderness, Frank, DISA Senior Executive. 1999. Telephone interview by author, 13 January, Washington, DC.

Hungarian telecommunications official. 1996. Interview by author, September, Budapest.

Knotson, Kalle, Joint Spectrum Center Engineer. 1999. Telephone interview by author, 13 January, Washington, DC.

Lee, William C. Y. 1997. *Mobile communications engineering*: New York, NY: McGraw Hill.

Lawlor, Maryann. 1997. Science board task force challenges, defensive information warfare status. *Signa*l, September, 94.

Macgregor, Douglas A. 1997. *Breaking the phalanx*: Washington, DC: Center for Strategic and International Studies.

Mager, Pete. 1998. Radio spectrum: Adequacy and availability to support Joint Vision 2010, *Army Communicator*, Spring, 11-14.

National Telecommunications and Information Agency. 1993. *The New spectrum mud wrestle, WARC 1992 and beyond.* Washington, DC: The International Communications Studies Program.

_________. *1993 National Spectrum reallocation*, final report. Washington, DC: GPO.

_________.1998. Myths vs. realities. Washington, DC. National Telecommunications and Information homepage. Available from http:www.ntia.gov/ntiahome/myths.html; Internet; accessed 3 October 1998.

Robinson, Clarence A. 1997 Computing advances spark spectrum management tools. *Signal,* February, 55-59.

U.S. Army. 1994, Army Regulation 5-12, *Army management of the electromagnetic spectrum*. Washington, DC: Department of the Army.

_________. 1983. Field Manual 24-24, *Radio and reference data.* Washington, DC: Department of the Army.

_________. 1994. Army Regulation, 24-2, *Radio frequency management*. Washington, DC: Department of the Army.

_________. 1994. *Army science and technology plan,* Vol 1. Washington, DC: Department of the Army.

_________. 1996. Field Manual 100-6, *Information operations.* Washington, DC: Department of the Army.

_________. 1998. Field Manual 24-32, *Digitization.* Washington, DC: Department of the Army.

_________. 1998. "*Spectrum reallocation impacts: DOD response to office and management and budget.*" Washington, DC: Department of the Army. Typewritten.

U.S. Department of Commerce. 1992. *Manual of regulations and procedures for federal radio frequency management*. Washington, DC: GPO.

_________. 1992. *Federal Spectrum Management: A guide to the NTIA Process*. Washington, DC: GPO.

_________. 1995. *Global information infrastructure: Agenda for cooperation.* Washington, DC: GPO.

_________. 1991. *Creating new technology bands for emerging technologies.* Washington, DC: GPO.

_________. 1997. *Where do we go from here? The FCC spectrum auctions and the future of radio spectrum management.* Washington, DC: GPO.

_________. 1997. *Federal frequency spectrum sale could impair military operations.* Washington, DC: GPO.

_________. 1997. *Joint Vision 2010.* Washington, DC: GPO.

U.S. General Accounting Office. 1987. *Radio Frequencies: earlier coordination could improve system use and cost*: Washington, DC: GPO.

_________. 1987. *Report to the Secretary of Defense on radio frequencies.* Government Printing office: Washington, DC: GPO.

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